# THE EPIDEMIOLOGY OF "SICK PUBLIC BUILDINGS"

*by THEODOR STERLING and S.KLEVEN*

Dr. Sterling is a Professor in the Faculty of Applied Science at Simon Fraser University, Burnaby, British Columbia, Canada. He is a Fellow of the American College of Epidemiology, the Canadian Committee of Scientists and Scholars, the American Association for Achievement of Science and the American Statistical Association.
Ms. Kleven received her Master of Science in Kinesiology in 1986. She is a Research Analyst with Theodor D. Sterling Limited.

## ABSTRACT

The indoor environment of modern buildings, especially those designed for commercial and administrative uses, constitute a unique ecological niche with its own biochemical environment, fauna and flora. Sophisticated construction methods, new materials and machinery required to maintain the indoor environment of these enclosed structures produce a large number of chemical by-products and permit the growth of many different microorganisms. Because modern office buildings are sealed, the regulation of humidification and temperature of ducted air presents a dilemma, since different species of microorganisms flourish at different combinations of humidity and temperature. If the indoor environment of modern office buildings is not properly maintained, the environment may become toxic to the occupants' health. Such buildings are classified as Sick Buildings. A review of the epidemiology of building illness is presented. The etiology of occupant

illnesses, sources of toxic substances, and possible methods of maintaining a safe indoor environment are described.

## INTRODUCTION

Disease has always been strongly associated with the type and use of structures humans occupy. Food, drink, waste products and the presence of any other organic substances (including animals) harbor infectious organisms. With the discoveries of the vectors by which infectious organisms invade a human host have come innovations in building technology and mechanical appliances that cook, store and preserve food, eliminate human waste, and help keep the indoor environment of a building reasonably free of harmful infectious agents. In addition, although not recognized as a source for disease, are toxic chemicals found indoors. The link between the by-products of combustion of biomass materials burned indoors (such as wood, coal, and later on, kerosene and natural gas) and subsequent chronic disease was not recognized until relatively recently. In general, while the type of structure in which people lived and worked may have had a profound influence on their health, specific antecedents of disease were not so much related to a structure of a building as to a specific point source within the structure (e.g., wastes, storage of food, fires used for heating or cooking).

At the start of the twentieth century, a new type of structure became prominent; that of a large public building devoted to commercial or administrative uses. As these buildings grew in size they created a uniquely new environment plagued with problems, primarily because of the great volume of air they enclosed. In addition, the by-products of the machinery required to make these buildings function also created problems. The requirements of air intake, heating, cooling and distribution, and elimination of by-products of human occupation and machinery created needs for massive ducting throughout the full height of the structures, which led to demands for building designs that were large enough to accommodate the machinery necessary to make human occupation possible. (These included the seldom mentioned flush toilets, without which, skyscrapers would be uninhabitable.) However, the main criteria of these early buildings was not so much to eliminate pollutants created inside the building but to prevent infiltration of pollutants from outside. This was especially true for soot from burning coal

used for industrial plants and residences. Initially, attempts were made to regulate the indoor climate by warming and cleaning intake air and then ducting it throughout the building. Outstanding examples of this new technology are the Royal Victoria Hospital in Belfast, built in 1903, and the Larkin Administration Building in Buffalo, New York, built in 1906. From these pioneering efforts came the idea that to condition the indoor environment of a large building and to remove some of the sources of discomforts coming from outdoors, well tempered air must be provided indoors. These initial attempts were further supported by the desire to eliminate the wells for lighting and ventilating the inside of buildings. These wells occupied space that could more profitably be used in commercial buildings for additional office space.

It took the first half of the twentieth century to learn how to supply power to, and maintain these large office buildings. However, starting in the late 1960's, the buildings in the commercial districts of modern cities began to change. New buildings were erected that were sealed structures of great height that relied entirely on mechanical means to regulate their indoor environments. Buildings that used operable windows for ventilation and circulating steam or hot water for heat were replaced by structures with ducted air that was centrally heated or cooled. Advancements in chemistry made possible the manufacturing of entirely new fabrics that were used to cover floors and walls, and construct furniture. Formaldehyde resins were used extensively for particle boards from which furniture or wall panels were constructed and in glues to affix carpets to the floors. A variety of machines were introduced, of which perhaps the most important, from an epidemiological perspective, are the photocopier and certain types of air conditioners. To clean the vast floor areas various carpet shampoos and industrial cleaners were used that sometimes left toxic residues. Filters were used to clean the air circulated by means of the ducting systems. At the same time, however, these filters and duct systems became breeding grounds for various types of organisms (as were some carpets). In short, the modern buildings provided conditions to create a complex ecological niche that became a possible source for human disease.

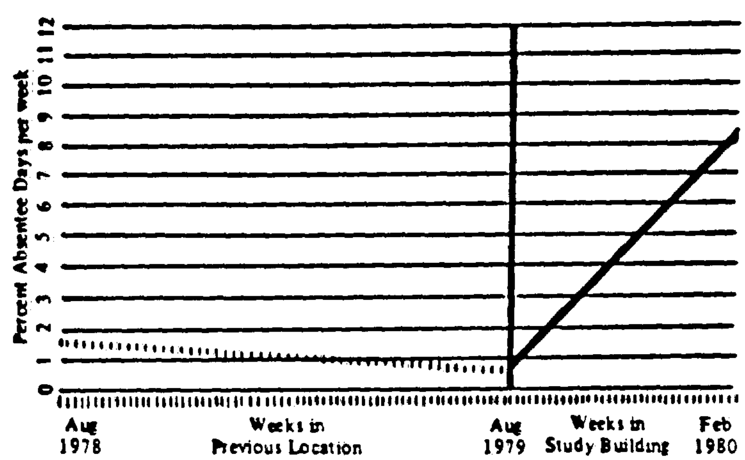
## CAUSES OF BUILDING ILLNESS

Since the early 1970's, occupants of hundreds of modern sealed office

buildings throughout North America have reported similar health and comfort complaints *(Berglund, 1984)*. These buildings are commonly referred to as "sick buildings" and the epidemic of complaints by the occupants of these buildings has been defined by the World Health Organization as "Sick Building Syndrome" (*WHO*, 1982). Sick buildings are identified by a very high prevalence of specific health symptoms among the occupants which include: headache, eye problems (irritated, sore, dry, itching, or watering eyes), nasal problems (stuffy, runny, or irritated nose), throat problems (dry, sore, or irritated throat), chest problems (chest tightness, difficulty breathing), fatigue and lethargy (including sleepiness and weakness), skin abnormalities (dry, itchy, or irritated skin), and problems maintaining concentration at work (*Sterling, E*, 1983; *Hedge*, 1984; *Finnigan*, 1984; *Robertson*, 1985). In four studies the incidence of "building illness" was found to be at least twice that in naturally ventilated buildings (*Turiel*, 1983; *Hedge*, 1984; *Finnigan*, 1984; *Robertson*, 1985). It has also been suggested that other symptoms, such as skin rashes/irritation/dryness, nausea, dizziness, and respiratory problems (wheeze, shortness of breath, chest tightness) are characteristically more prevalent in sick buildings (*WHO*, 1983; *Stolwijk*, 1974; *Hawkins*, 1985). Finally, there have been complaints in some buildings of increased spontaneous abortions. However, most of these complaints have been anecdotal, and because of the difficulty of counting them, such abortions have not been verified.

The effect of sick buildings on occupant health is demonstrated by the study of *Sterling, E. and Sterling, T.* (1983) of a group of office workers who moved from an old fashioned building with window ventilation and lighting to a modern sealed structure. Absentee data were supplied for a period of one year before and seven months after the study group moved into the new building. The percent of absent days was calculated for all staff members. The study group served as its own control, making possible the comparison of absentee prevalence before and after the move to the new enclosed structure. Figure 1 shows the percentage of days absent for the study group beginning in August 1978 and ending in February 1980. The vertical solid line divides the graph into two parts, before and after the move. There is no trend in absenteeism before the move. Most weekly absences were below 3% and there were no absences at all for 40% of the weeks. The dotted line is the line of best fit resulting from fitting a linear equation to the data for the period of time prior to the move into the study building. The slope of this line is not significantly different from zero. The coefficient of determination

Figure 1. Absentee rate scattergram pre- and post- occupancy of the study building




From Sterling and Sterling (1983).

($r^2$) between absentee rate and time is 0.03 and the correlation coefficient ($r$) is -0.17, indicating that no increasing (or significantly decreasing) trend is apparent.

The solid line is the line of best fit of the data for the period of time after the move. The positive slope of 2.66 approximates the linear trend of absentee rates per week in the study building during initial occupancy. The $r^2$ in this case is 0.53 and $r$ is .73 ($p < .01$). This significant trend clearly shows that absenteeism was increasing after the move into the new building.

Figure 2 details the striking difference in specific complaints in a cross group comparison between a study and control group. The control group oc-



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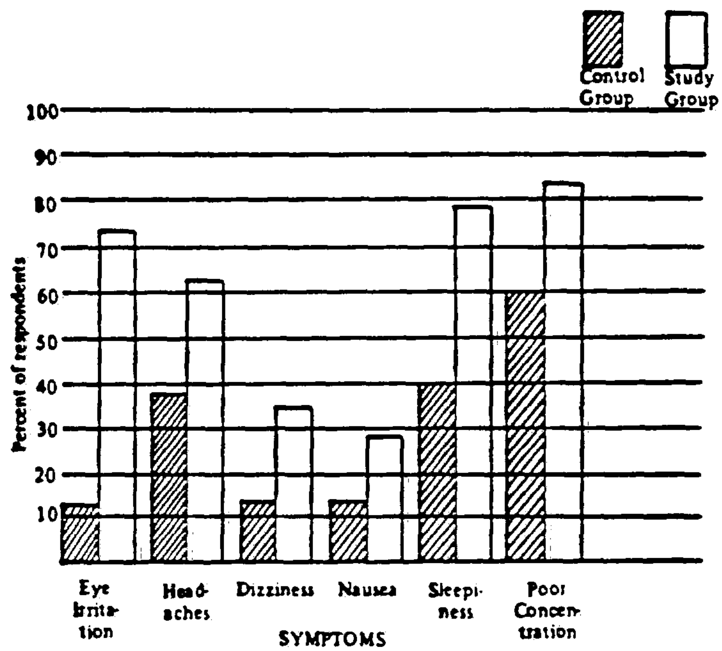
Figure 2. Symptom distribution by group.




From Sterling and Sterling (1983).

cupied a building with operable windows for ventilation and hot water for radiant heat.

## SPECIFIC CAUSES OF BUILDING ILLNESS

A number of studies of sick buildings have been able to isolate instances where the cause of health symptoms could be isolated and eliminated by

taking appropriate measures. Such examples contribute important information of how to prevent building wide epidemics.

In 1982 my associates and I started to create an archive of reports of studies of sick buildings (*Collett*, 1987). This archive now contains reports of almost 500 building studies conducted in North America (the majority are located in the U.S). These studies were completed by industrial hygienists and investigators working for the National Institute of Occupational Safety and Health (*NIOSH*) of the United States, the U.S. Center for Disease Control, various municipal and state agencies, universities and other research centers.

Here are some examples identified as contributing causes of building illness:

**Formaldehyde:** From insulation (*Gunter*, 1981; *Fannick*, 1981) and offgasing from materials containing formaldehyde resins (*Chrostek*, 1981; *Konopinski, 1980; Coy, 1982).*

**Industrial cleaners:** From the residues of industrial carpet shampoos (*Kreis*, 1981; *Robertson*, 1980).

**Solvents:** From fresh ink on checks in poorly ventilated areas (*Thoburn*, 1981) and printing solvents (*Gunter*, 1981).

**Perchloroethylene:** From the duct work of a dry cleaner. The gas travelled above the ceiling to other stores in the same complex (*Thoburn*, 1981).

**Fiber Glass:** Disseminated through the ventilation system (*Kreis*, 1981).

**Ozone:** (*Shoemaker*, 1977; *Gunter*, 1981).

**Automobile exhaust:** Entered through the ventilation inlets (*Nudelman*, 1979; *Leiderman*, 1982).

**Photocopiers:** From a hot oil process, use of methyl alcohol (*Prior*, 1981; *Apol*, 1981; *Fannick*, 1980; *Chrostek*, 1981).

The causes of sick building syndrome are very often unclear. Usually, however, the health symptoms in such buldings can be resolved by increasing the fresh air supply (*Salisbury*, 1981; *McManus*, 1985; *Chio*, 1985).

A summary of what is known about specific causes of sick building syndrome was provided by the U.S. National Center for Occupational Safety and Health (*NIOSH*) in 1984. The findings from 203 of NIOSH's investigations undertaken up to the end of 1983 were reviewed and tabulated by the Health Hazards Evaluation Branch of NIOSH (*Melius*, 1984). Of these 203 studies, 17.7% attributed the health symptoms to indoor air contamination (e.g., from sources such as industrial cleansers or photocopiers), 10.3% to outdoor air contamination (e.g., from misplaced air intake vents that would draw gasoline fumes from garages or bus stations), 3.4% to building contamination (e.g., offgasing of formaldehyde from wall panels, glues and resins in carpets, and furniture made from particle board), 40.3% to inadequate ventilation, 3% to hypersensitivity pneumonitis (often caused by the use of humidifiers), 2% to cigarette smoking, 4.4% to humidity, and 1% to noise and lighting. The remaining 10% of the studies did not find a cause for health symptoms. A review by Health and Welfare Canada (*HWC*) of 94 building studies gave similar results (*Kirkbride*, 1985). In this review, 68% of the studies attributed the cause of health symptoms to inadequate ventilation (e.g., poor air circulation, inadequate fresh air intake, and poor temperature and humidity control) 10% to outdoor contaminants (e.g., motor vehicle exhaust entering the building), 5% to indoor contaminants (e.g., photocopy machines and tobacco smoke; the report does not state to what extent the cause of building illness was due to the use of copy machines or cigarette smoke), 2% to building gases (e.g., formaldehyde, organic glues and adhesives), and the remaining 15% to unknown sources. (Because of present concerns with smoking, all NIOSH and HWC studies paid special attention to smoking as a possible cause of sick buildings. It is of interest, therefore, that smoking was said to be a major cause of complaint only in 2% to 5% of the sick building investigations. Removing the smoker entirely, then, may not affect health and comfort problems in 95% to 98% of sick buildings.)

## BIOCHEMICAL SUBSTANCES IN MODERN BUILDINGS

A wide range of substances have been measured inside modern office buildings. Some of these substances are known, and others are thought to be associated with various diseases. A summary of the measured substances was compiled by the U.S. Environmental Protection Agency and published in the Environment Protection Agency Indoor Air Quality Implementation Plan (1987) under the title "Common Indoor Pollutants, Their Sources and Known Health Effects" (*EPA*, 1987). (Because of its importance, this list is included as an APPENDIX.)

In summary, the EPA table lists 73 common indoor pollutants that are known to be toxic, although not necessarily at the level of concentration found in most buildings. Of these 73 substances, 38 are attributable to building components and appliances, 26 by the evaporation of drinking water, 17 by outdoor air, 16 by products used for cleaning and maintenance, 12 by tobacco smoke, and 9 by vehicles exhaust trapped in garages. Tobacco smoke was singled out by the Environmental Protection Agency because of its visibility. However, with the exception of nicotine and nicotine derivatives, almost all of the substances from tobacco smoke are also derived from a number of other sources. For example, carbon monoxide (CO), besides being present in tobacco smoke, is usually present in much greater quantities, or produced by, HVAC systems, garages, outdoor air and gas stoves; styrine also comes from furnishings and drinking water; benzene from garages and drinking water; methyl chloride from drinking water, pyridine from outdoor air; acetone from cleaners, waxes, adhesives, cosmetics and outdoor air; acroline from the combustion of various products (as are other substances such as formaldehyde or respirable particles); benzo(a)pyrene from automobile exhaust and drinking water; and analine is a by-product from various activities. Sources, other than tobacco, are not given for methylamine and hydrazine. (This may be a result of too few measurements available for these two substances, rather than a real absence of these substances from the combustion of materials other than tobacco.)

In summary, the EPA list demonstrates that there are multiple sources for many chemicals and substances known, or thought, to be toxic. Because

there are so many alternative sources for most substances found in a building, the best method to deal with indoor exposure to biochemicals is to dilute them by adding an adequate amount of fresh air.

## THE INDOOR ECOLOGY

A general rule of ecology is that every spot capable of supporting life will be occupied by some form of life. This is just as true for the indoor environment as it is for the Arctic Tundra. Countless substances, necessary to sustain life, are found indoors, especially in the ducts and ventilation system of a building and in all places where moisture may gather. Dusts, much of which contain both the staff of life and microbial and viral life itself, are brought into buildings through fresh air intake and on the clothing, hair and skin of building occupants and visitors. Some of the microorganisms can cause violent physiological reactions in humans.

Perhaps the best known example of the possible virulence of indoor microbial life is Legionnaires' Disease. Legionnaires' Disease, named after an explosive outbreak of pneumonia in a group of Legionnaires attending an American Legion convention in Philadelphia in 1976, is a pneumonia-like reaction to the Legionella Pneumonphilia bacterium. The bacterium requires the presence of certain algae, which usually grow in cooling towers at specific temperatures, for growth (*Fraser*, 1977). Pontiac Fever, named after a health department building in Pontiac, Michigan, U.S., in which the syndrome was first described, is a strain of Legionnaires' Disease (*Kaufman*, 1981). Recurrences of Legionnaires' Disease and Pontiac Fever are documented from time to time, very often in hospitals, and are always connected with poor maintenance of cooling towers (*Friedman*, 1987; *Garbe*, 1985; *Conwell*, 1982; *Kaufmann*, 1981; *Fisher-Hoch*, 1981).

Legionnaires' Disease, however, is just the tip of the iceberg. There are many places in a building in which infectious organisms (bacteria, viruses, fungi, mites) and pollen may flourish. As an example, my associates and I reported allergic and infectious reactions caused by humidifier contaminants (*Arundel*, 1986, see TABLE 1). In general, organic materials will flourish at all levels of relative humidity. Figure 3 describes the relationship between

**TABLE 1. REPORTS OF ALLERGIES CAUSED BY HUMIDIFIER CONTAMINANTS**

| Subjects | Diagnosis | Contaminant | Confirmation |
|---|---|---|---|
| 11 office workers | Fever, malaise, chest tightness, polyuria | Acanthamoeba spp. | Symptoms disappeared 4 weeks after the humidification system corrected |
| 26 office workers | Fever, chills, cough, dyspnea | Unknown, possibly protozoa | No symptoms 5 months after humidification system removed |
| 24 factory workers | Extrinsic allergic alveolitis | Phialophora spp., Cephalosporium, Fusarium, Gliomastix | Precipitins to humidifier water, symptoms ceased after alteration to system |
| 20 factory workers | Fever, chills, dyspnea | Pseudomonas endotoxins in humidifier | Not stated |
| 3 housewives | Recurrent acute interstitial lung disease | Thermoactinomyces in home humidifier | Positive bronchial challenge to hemophile |
| 1 male | Recurrent pneumonia | Fungi and bacteria in humidifier | Challenge with vaporizer aerosol positive, specific agent unidentified |
| 1 female | Recurrent hypersensitivity pneumonitis | Thermotolerant bacteria in home humidifier | Positive bronchial challenge, positive serum |
| 1 female | Hypersensitivity pneumonitis | Unknown organisms in home humidifier | Positive pulmonary challenge to humidifier water, all family members showed precipitin reactions |
| 1 female | Hypersensitivity pneumonitis | Cephalosporium in home humidifier | Precipitins to antigens |
| 2 asthmatics | Asthmatic episodes | Yeast contaminated aerosols in humidifier | Recurrent symptoms on re-exposure |
| 1 female | Pneumonitis, recurrent chills fever, cough, dyspnea | Thermophilic actinomycetes in home humidifier | Positive bronchial challenge |
| 1 male | Hypersensitivity pneumonitis | Thermoactinomyces vulgaris in console home humidifier | Symptoms disappeared when humidifier removed, precipitating antibodies |
| 1 female | Hypersensitivity pneumonitis | Thermoactinomyces vulgaris in humidifier | Precipitins against agent |

From Arundel et al. (1986).



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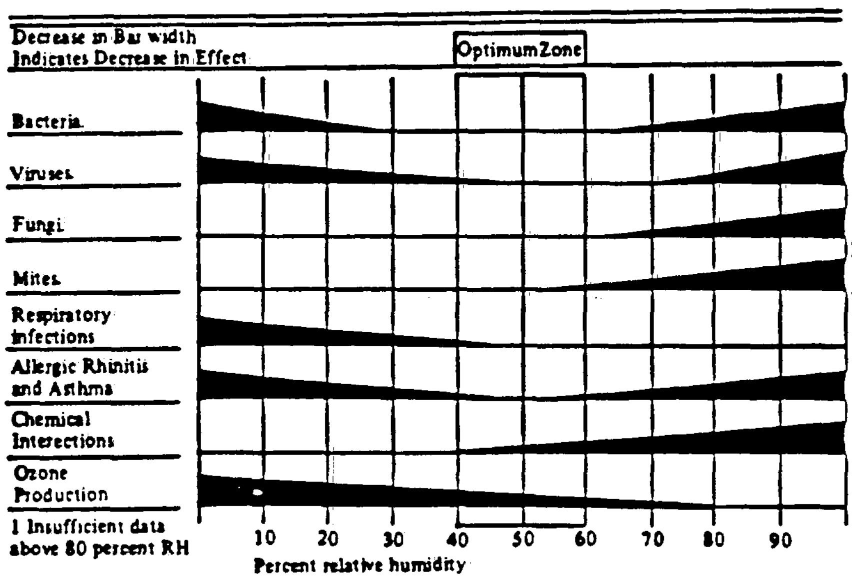
Figure 3. Optimum relative humidity range for minimizing adverse health effects.




From Arundel et al (1986).

the humidity and growth of various types of bacteria, viruses, fungi, and mites, respiratory infections, atopic reactions, chemical interactions, and ozone production. As one can see from this figure, the growth of organic materials is minimized if the relative humidity in a building is maintained between 40% and 60%.

## CONCLUSION

Modern office and public buildings create an indoor environment that is poorly understood and may be exceedingly hostile to occupants unless its hazards are clearly recognized. Because of the multiplicity of hazards and the chain of events that lead to physiological reactions in humans to contaminated indoor environments, no single and/or simple solution(s) is available. Adequate attention to ventilation and fresh air supply will eliminate or minimize many of the eye, throat, nose, and/or skin irritations caused by chemicals in the air by diluting them to a safe level. However, insofar as outdoor air contains a large number of toxic pollutants, it should be clear that a well ventilated building may only be able to maintain outdoor levels of cleanliness.

There are some instances, however, in which modern technology can improve and maintain the cleanliness of indoor air as compared to outdoor air. For instance, adequate filtering systems may remove much of the dust found outdoors and air conditioning and heating systems can adjust for climatic conditions. These technologies, however, need to be applied with a full understanding of the possible effect that application might have on human health. For example, while filters will remove unwanted dusts and respirable particles from the outdoor air, such filters also offer a medium for growth for a variety of bacteria and other infectious agents. Therefore, filters should be changed very frequently, which is a building maintenance expense. Similarly, aerosols from cooling towers need to be kept away from fresh air intakes in buildings. This requires careful planning in the placement of these air vents. (In addition, fresh air intake vents should not be placed near street level or garages where they will take in exhaust from motor vehicles and exhaust vents).

Finally a working relationship needs to be established between building engineers, architects, and epidemiologists. For instance, in studying a building with my associate, Elia Sterling (architect), we found that the high absentee rate and prevalence of irritation complaints was caused by the formation of indoor smog. A large amount of air was passed over high ultraviolet producing lighting fixtures. The impact of the high level of ultraviolet (*UV*)

light on the air stream was similar to that of the sun on outdoor pollutants. Ultraviolet light is a cause of outdoor smog in such cities as San Francisco or Los Angeles. Similar UV emissions can cause the formation of smog indoors. We learned from this particular building that air vents should not be constructed to serve as lighting fixtures and high UV sunlight simulating fluorescent lighting should not be used (*Sterling, E. & Sterling, T.* 1983). We also learned that the epidemiology of sick buildings requires a multidisciplinary approach that should include architects, industrial hygienists and ventilation engineers.

## REFERENCES

APOL A.G. 1981. Health Hazard Evaluation Report, HETA 81-177, 1778-1988. University of Washington, Seattle, WA. NIOSH, Cincinnati, OH.

ARUNDEL A., STERLING E.M., BIGGIN J.H., STERLING T.D. 1986. Indirect Effects of Relative Humidity in Indoor Environments. Environmental Health Perspectives, 65:351-361.

BERGLUND B., LINDVALL T., SUNDELL T. (eds) 1984. Indoor Air (Vols. 1-5) Proceedings 3rd International Conference on Indoor Air Quality and Climate, Stockholm, August 20-23.

CHIO A., PIACITELLI L. 1985. Health Hazard Evaluation HETA 85- 196. Family Development Inc. Office, Parkersburg, WV. NIOSH, Cincinnati, OH.

COLLETT C.W., STERLING E.M., WEINKAM J.J., STEEVES J., MCINTYRE E.D. 1987. The Building Performance Database: An Analytical Tool for Indoor Air Quality Research. Proceedings Indoor Air '87.

CHROSTEK W. 1981. Health Hazard Evaluation Report HETA 81-251- 925, Skil Corporation, Philadelphia, Pensylvania. National Institute for Occupational Safety and Health, Cincinnati, OH.

CHROSTEK W. 1981. Health Hazard Evaluation Report HETA 81-084- 916, State College, Kutztown, Pensylvania. National Institute for Occupational Safety and Health, Cincinnati, OH.

CONWILL D.E., WERNER S.B., DRITZ S.K., BISSETT M., COFFEY E., NYGAARD G., BRADFORD L., MORRISON F.R., KNIGHT M.W. 1982. Legionellosis--the 1980 A San Francisco outbreak. American Review of Respiratory Disease, 126:666-669.

COYE M.J., BELANGER P.L. 1982. Health Hazard Evaluation Report, HETA 82-176-1236. U.S. Customs Service, Patrol Division Office. Treasure Island, San Francisco, CA. NIOSH, Cincinnati, OH.

FANNICK N. 1980. Health Hazard Evaluation HE 80-6-667, Seiser and Wilpon, New York, NY. NIOSH, Cincinnati, OH.

FANNICK N. 1981. Health Hazard Evaluation Report HETA 81-241-970. National Park Service, Patchogue, NY. NIOSH, Cincinnati, OH.

FINNEGAN M.J., PICKERING C.A., BURGE P.S. 1984. The sick building syndrome: prevalence studies. British Medical Journal, 289:1573-1575.

FISHER-HOCH S.P., BARTLETT C.L., TOBIN J.O., GILLETT M.B., NELSON A.M., PRITCHARD J.E., SMITH M.G., SWANN R.A., TALBOT J.M., THOMAS J.A. 1981. Investigation and control of an outbreak of legionnaires' disease in a district general hospital. Lancet, 1:9932-9936.

FRASER D.W., TSAI T.R., ORENSTEIN W., PARKIN W.E., BEECHAM H.J., SHARRAR R.G., HARRIS J., MALLISON G.F., MARTIN S.M., MCDADE J.E., SHEPARD C.C., BRACHMAN P.S., Field Investigation Team. 1977. Legionnaires' Disease. Description of an Epidemic of Pneumonia. The New England Journal of Medicine, 297:1189-1197.

FRIEDMAN S., SPITALNY K., BARBAREE J., FAUR Y., MCKINNEY R. 1987. Pontiac Fever outbreak associated with a cooling tower. American Journal of Public Health, 77:568-572.

GARBE P.L., DAVIS B.J., WEISFELD J.S. 1985. Nosocomial Legionnaires' disease. Epidemiologic demonstration of cooling towers as a source. Journal of the American Medical Association, 254:521-524.

GRIST N.R., REID D., NAJERA R. 1979. Legionnaires' disease and the traveller. Annals of Internal Medicine, 90:563-564.

GUNTER B.J. 1981. Health Hazard Evaluation Report, HETA 81-057-905. Jefferson County Mental Health Center, Wheat Ridge, CO. NIOSH, Cincinnati, OH.

GUNTER B.J. 1981. Health Hazard Evaluation Report, HETA 81-006- 849. Mountain Bell, Fort Collins, CO. NIOSH, Cincinnati, OH.

GUNTER B.J., THORBURN T.W. 1981. Health Hazard Evaluation Report HETA 81-108-883. Tri Valley Federal Credit Union, East Helena, Montana. NIOSH, Cincinnati, OH.

HAWKINS L.H. 1985. "Sick Building Syndrome" - Possible causes and symptoms. Paper presented at The Institute of Occupational Safety and Health Seminar on Office Safety, June 28.

HEDGE A. 1984a. Suggestive evidence for a relationship between office design and self-reports of ill health amongst office workers in the United Kingdom. Journal of Architectural and Planning Research, 1:163-174.

HEDGE A. 1984b. Ill health among office workers: an examination of the relationship between office design and employees well- being. In: E. Granjean (ed.) Ergonomics and Health in Modern Offices, page 46-51, London: Taylor & Francis.

HEDGE A., STERLING E.M., STERLING T.D. 1986. Building Illness indices based on questionnaire responses. Proceedings IAQ '86 Managing Indoor Air for Health and Energy Conservation.

KAUFMANN A.F., MCDADE J.E., PATTON C.M., BENNETT J.V., SKALIY P., FEELEY J.C., ANDERSON D.C., POTTER M.E., NEWHOUSE V.F., GREGG M.B., BRACHMAN P.S. 1981. Pontiac fever: isolation of the etiologic agent (Legionella pneumophillia) and demonstration of its mode of transmission. American Journal of Epidemiology, 114:337-347.

KIRKBRIDE J. 1985. Sick Building Syndrome: Causes and Effects. Health and Welfare Canada, Ottawa, Ontario.

KONOPINSKI V.J. 1980. Formaldehyde in Office and Commercial Environments. Indiana State Board of Health, Indianapolis, Indiana.

KREISS K. 1981. Pueblo Fiberglass Investigation. Colorado Department of Health, Division of Disease Control and Epidemiology.

KREISS K., GONZALEZ M., CONRIGHT K., SCHEERE A. 1981. Respiratory Irritation due to Carpet Shampoo: Two Outbreaks. Centers for Disease Control, Atlanta, GA.

MCMANUS K.P. 1985. Health Hazard Evaluation HETA 85-396. Barnes Building, Boston, MA. NIOSH (National Institute for Occupational Safety and Health), Cincinnati, OH.

MELIUS J., WALLINGFORD K., KEENLYSIDE R., CARPENTER J. 1984. Indoor Air Quality - The NIOSH Experience. Annual American Conference of Government Industrial Hygienists.

NUDELMAN H. 1979. SP 78-2, St. Luke's Hospital, New York, NY. Interdepartmental Memo, City of New York.

PRYOR P., RENO S.J. 1981. Health Hazard Evaluation HETA 81-305- 961. Aurora Schools, Aurora, CO. NIOSH, Cincinnati, OH.

ROBERTSON A.S., BURGE P.S., HEDGE A., SIMMS J., GILL F.S., FINNEGAN M.J., PICKERING C.A., DALTON G. 1985. Comparison of health problems related to work and environmental measurements in two office buildings with different ventilation systems. British Medical Journal, 291:373-376.

ROBINSON P.A., WINKLER W.G., GREGG M.B. 1980. EPI 80-41-2. Respiratory Illness in Conference Participants - Washington, D.C. Public Health Service, CDC, Atlanta, GA.

SALISBURY S. 1981. Health Hazard Evaluation Report, HETA 81-002- 875. Atlanta Jewish Federation, GA. NIOSH, Cincinnati, OH.

SHOEMAKER W. 1977. Health Hazard Evaluation 76-70-367, Sperry Univac Corporation, Philadelphia, Pensylvania. National Institute for Occupational Safety and Health, Cincinnati, OH.

STERLING E., STERLING T. 1983. The impact of different ventilation levels and fluorescent lighting types on building illness: An experimental study. Canadian Journal of Public Health, 74:385-392.

STOLWIJK J.A.J., PIERCE J.B. 1984. The "sick building syndrome. In: Berlund B., Lindvall T., Sundell J. (eds.) Indoor Air, Vol. 1: Recent advances in the health sciences and technology, Proceedings of the International Conference on Indoor Air Quality and Climate, Stockholm, August 20-24, pp. 23-29.

THOBURN T.W. 1981. Health Hazard Evaluation Report, HETA 81-005- 834. Public Employees Retirement Association. Denver, Colorado. NIOSH, Cincinnati, OH.

TURIEL I., HOLLOWELL C.D., MIKSCH R.R., RUDY J.V., YOUNG R.A. 1983. The effects of reduced ventilation on indoor air quality in an office building. Atmospheric Environment, 17:51-64.

WORLD HEALTH ORGANIZATION (WHO), 1982. Indoor Air Pollutants: Exposure and Health Effects Assessment. (Working Group Report, Nordlingen, Euro reports and studies no. 78, WHO, Copenhagen).

WORLD HEALTH ORGANIZATION (WHO), 1983. Indoor air pollutants: exposure and health effects, EURO Reports and Studies 78.